ATLAS-CMS Experimental Combination
3rd General Meeting of the LHC EFT Working Group

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22.11.2021
Introduction

- Long-term goal: accurate likelihood-level global EFT combination of ATLAS and CMS
- Want to perform combination exercise already now
  - Establish conventions
  - Identify problems
- Simplified:
  - Few measurements
  - Mainly multivariate Gaussian approximation
  - Don’t want to produce physics result at this stage
  - Prepared to take some shortcuts
- In parallel: more complex combinations planned within experiments
- Happy for feedback and people joining the effort
Sketch of the exercise 1/2

1. Agree on models and conventions (see twiki)
   - SMEFT basis, input parameters, flavour symmetry, operators
   - Parametrization: linear/quadratic?, LO/NLO?, parameter settings...
   - Uncertainties: what to include, how to correlate
   - Some details later

2. Identify input analyses
   - From EW, Higgs, and top sector
   - With reasonable physics case for combination
   - For re-interpretation need: cross-sections, covariance, and Rivet routine (EFT interpretation in paper *not* a requirement)
   - Collected list of candidate analyses – possible choices discussed later

3. Derive particle level parametrizations with agreed models and conventions
   - Typically MadGraph+SMEFT(sim\|atNLO) → Pythia8 → Rivet
   - ATLAS and CMS could run each others Rivet routines for some processes, as cross check
   - Also cross-check with theory publications
4. Create models in RooFit
   ▶ Multivariate Gaussian, potentially full model in some cases
   ▶ Nuisance parameters for systematics that should be correlated

5. Perform first combined fits
   ▶ Linear and quadratic, 1D and multidimensional
   ▶ Start with analyses for which we first finish steps 1-4 (possibly start with few EW measurements)

6. Study correlation of uncertainties
   ▶ For theory uncertainties, some test cases for experimental uncertainties
   ▶ Publically available information not enough to correlate all relevant parameters

7. More in-depth studies
   ▶ More involved schemes to evaluate theory uncertainties and validity
   ▶ Acceptance corrections (e.g. for decays in STXS analysis)
   ▶ Study of overlap in event selections
Conventions: Basis, flavour structure, operators

Conventions from twiki

Interim Conventions for a first EFT Combination between LHC experiments

- Simplified for a first combination between LHC experiments – individual experiments will likely perform more complex combinations
- Black text in twiki: already agreed
- Red text in twiki: recent ATLAS additions (to be checked by CMS)

Overview of the main points

- Dim-6 operators in Warsaw basis
- \( U(2)^3_{q,u,d} \times U(3)^2_{l,e} \) aka topU3l flavour symmetry as defined in CERN-LPCC-2018-01 (currently not available for SMEFTatNLO(?)
- \( G_F, m_W, m_Z \) input parameter scheme (values will be provided)
- Will provide list of operators – in principle all that affect processes in question (consider to exclude e.g. four-fermion operators, for simplicity)
Consider all operators with significant impact on given process

Parametrization derived on tree-level, except for loop-induced process (SMEFTatNLO for $gg \rightarrow H$, [1807.11504] for $H \rightarrow \gamma\gamma$)

Single insertion of operators

Both linear and quadratic dependence (incl cross-terms with two different Wilson coefficients) will be computed

Factorize production/decay for Higgs (but not for weak bosons)

Corrections for total width or propagator corrections (available in SMEFTsim3.0) to be taken into account

Will synchronize PDF, scale, and additional settings (e.g. mass, merging scale, ...) for calculation of parametrization

For a very quick first combination linear-only parametrization could be used

EFT parametrization as multiplied with “best” SM prediction
Uncertainties from missing higher orders, PDF, input parameters, etc on parametrization will be studied but likely not included in fit.

EFT truncation: for now only linear vs quadratic fits – MC-only mass cut (“clipping”) could be studied.

Try to harmonize nominal SM predictions as far as possible.

Theory uncertainty (on SM): correlation implemented by matching nuisance parameters.
  - Correlation of scale uncertainties notoriously difficult (which phase space regions and processes to correlate?)
  - PDF uncertainties: can be correlated for same PDF set but simple treatment with one NP for certain class of processes (e.g. diboson) might be more realistic in short term.

Experimental uncertainties:
  - Can try to correlate important ones (luminosity?)
  - Available information not enough to correlate all relevant parameters.
- Will mostly use multivariate Gaussian approximation (“χ² with correlation”)
  - Can be created from: measured cross section, covariance (or list of uncertainties), predicted SM cross section, EFT parametrization
  - Typically orders of magnitude faster to evaluate than full models
- Can also explore combination of Gaussian models with full likelihood from “detector level” measurement
- Technical framework: RooFit, shared workspaces
EW Inputs

- Possible candidates (under discussion)
  - ATLAS $WW$
  - ATLAS $WZ$
  - ATLAS EW $Zjj$
  - CMS $WW$
  - CMS $WZ$
  - CMS $W\gamma$

- Other candidates
  - ATLAS $4\ell$ (maybe too complex)
  - Also consider constrains from EWPD
Higgs Inputs

- Combined SMEFT interpretations of Higgs measurements already performed in STXS framework, parametrizations of STXS available or planned anyway

- Proposal: limited-scope STXS combination on covariance level
  - ATLAS 4ℓ, γγ, VH(b¯b) combination or subset thereof (e.g. γγ)
  - CMS γγ or 4ℓ

- Alternative proposals
  - Also explore combination with differential cross-section measurement or detector level measurement (e.g. CMS 4ℓ anomalous coupling analysis)
  - STXS combination with all channels
Top Inputs

- Possible candidates
  - CMS $t\bar{t}\gamma$
  - ATLAS $t\bar{t}Z$
  - CMS $t\bar{t}Z$ cross-section measurement(?)
  - CMS $t\bar{t}$ dilepton spin analysis

- Alternatives
  - CMS multi lepton (many detector-level categories)
  - CMS $t\bar{t}Z$ (detector level EFT interpretation)
Conclusion

- Technical combination exercise planned
- Common conventions being written down in twiki
- Initial list of measurements taking shape
- Should soon be possible to calculate parametrizations for agreed processes and framework – then start fitting
- Input and contributions welcome (also from theory)!
- Next area 4 meeting planned for Dec or Jan